Proof-of-Work Computing Primer

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DPO Proof-of-Work Computing Primer

Flexible data centers are an increasingly powerful tool for the energy sector to balance volatility and maximize profitability. Proof-of-Work security is among the first computing functions to reach economic viability within this framework.

Proof-of-Work data centers located at power generation assets can:

- Make renewable energy developments more profitable
- Reduce generation curtailments, especially for “stranded” renewable energy projects
- Make power plants easier to operate by guaranteeing an available offtake for all power generation
- Make the world’s power grids more stable and secure through demand response
- Lower end-consumers’ power prices
- Help with situations where electrical transmission infrastructure is inadequate or delayed
- Serve as a temporary offtake while awaiting grid interconnection studies
- Make wind repower processes more efficient and more profitable
- Operate in remote areas not viable for competitive solutions

Proof-of-Work’s (PoW) foundation is energy. Energy usage is the underlying mechanism that keeps a PoW network secure. We believe this activity should be thought of as energy management, using a new type of energy optimization infrastructure. The energy sector will benefit meaningfully by utilizing this process in a thoughtful and institutionally appropriate way.

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Introduction:

- **What is "mining?"** Bitcoin is "mined" by computers performing a series of calculations to unlock a portion (or block) of the underlying blockchain. There is no "mining" a physical good like gold or coal; instead these operations are better thought of as data centers performing a very specific computing function, and being rewarded for doing so. This "mining" activity is more technically known as Proof-of-Work (PoW) security.
- **How is bitcoin produced?** Every 10-minutes, a pre-defined amount of bitcoin is distributed by the bitcoin software protocol as a reward for those participants which are actively operating their computers during that 10-minute period.
- **What is a "pool?"** Not all computers receive the reward, only one does, so there is a good chance that a miner could receive nothing for weeks, months, or years if that miner is using only a small number of computers vs the millions in operation.
  - Miners get around this dynamic by joining "pools" which are large collections of miners operating in concert to share computing power and split rewards. The vast majority of major cryptocurrency miners operate in such pools. Rewards given to any miner in the pool are shared by all participants pro-rata with their computing power contribution.
    - Through this mechanism, miners can circumvent the unpredictability of receiving rewards and have essentially created a more stable and regular revenue stream. Generally, pooling costs a small portion of the sale proceeds from a miner's bitcoin rewards, typically 0.25-0.75%.
- **What is a "halving?"** When Bitcoin was first introduced in 2009, the reward given every 10-minute period was 50 bitcoin. The rewards have been programed to fall by 50% at regular predefined increments…every 210,000 blocks of the blockchain unlocked, or roughly every four years.
  - The initial halving occurred in November 2012, with the 10-minute block rewards halved from 50 to 25 bitcoin.
  - The second halving occurred in July 2016, with the 10-minute block rewards halved from 25 to 12.5 bitcoin.
  - The third halving occurred in May 2020, with the 10-minute block rewards halved from 12.5 to 6.25 bitcoin.
  - The fourth halving occurred in April 2024, with the 10-minute block rewards halved from 6.25 to the current rate of 3.125 bitcoin.
    - This will occur repeatedly until the last bitcoin is mined, which is expected to occur around the year 2140.
- **What is "difficulty?"** The rate at which new "blocks" are created is adjusted every 2,016 blocks (or approximately every two weeks). This adjustment means that, over time, the "difficulty" of mining a new block will increase as more computers begin mining (i.e. more computers are competing over the same 10-minute rewards), and will decrease as fewer computers mine, most of which is driven by the relative cost of power and the relative price of bitcoin.

The magic of Bitcoin's PoW programming is what makes this so compelling…institutional energy companies with large portfolios of generation assets are generally where the most stranded and undervalued energy exists. By vertically integrating flexible bitcoin data centers with energy assets, our clients will own and control the most economically competitive operations, and will therefore operate profitability even when many others cannot.

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Introduction (cont.):

What are the key drivers of volatility in the value of "mining?"

- For simplicity, think of the amount of block rewards distributed to miners as roughly pro-rata with that miner's processing power.
- If the price of bitcoin rises, the profit margin of miners will increase. This will lead to more miners entering the business, which will in turn reduce the amount of bitcoin each is awarded. Thus, a rise in price results in a rise in margin, which increases competition, resulting in a new natural equilibrium.
- If the price of bitcoin falls, the profit margin of miners will decrease. This will lead to fewer miners mining, which will in turn increase the amount of bitcoin each is awarded. Thus, a fall in price results in a fall in margin, which decreases the number of competitors, resulting in a new natural equilibrium.
- While BTC spot price declines reduce bitcoin data center profitability, it is not as meaningful as it might initially appear:
  - One must consider the supply and demand dynamics noted above. If there are fewer miners mining because some were pushed out due to compressing margins, those remaining capture more of the 10-minute block rewards.
    - **If BTC spot price declines by 25%, as the least profitable ASICs are turned off, surviving miners might expect to see revenues decline only 10-20%. This represents the built-in hedge that makes bitcoin mining safer than it seems.**
- Similarly, while BTC spot price growth increase data center profitability, this too is not as meaningful as it might initially appear:
  - One must again consider the supply and demand dynamics noted above. If there are now more miners mining because of the increased margin (and higher return on capex investment), the block rewards will now be shared by more participants, meaning each now captures a smaller share of the daily BTC rewards.
    - **If BTC spot price grows by 25%, the increasing margins and profitability will result in more computers being turned on, thereby offsetting much of the spot price increase for everyone, and revenues per computer may grow only minimally. This also represents the built-in hedge that makes bitcoin mining safer than it seems, but also limits upside in more bullish BTC spot price scenarios.**

Bitcoin data centers are more profitable and less volatile than many think.

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Introduction (cont.):

How does the "halving" affect volatility?

- As with the previous page, we can also infer some outcomes relating to the halving of block rewards:

- As the block rewards are halved on a pre-defined schedule, assuming all else is equal, EVERY BITCOIN MINER ON EARTH WILL HAVE ITS REVENUE CUT IN HALF.
  - E.g. if 1,000 miners are splitting 3.125 bitcoin every 10 minutes, those same 1,000 miners will be splitting 1.5625 bitcoin every 10 minutes after mid-2028.
  - Because those miners have the same energy costs, the same employee costs, and the same capex requirements regardless of how many bitcoin they receive in each 10-minute window, many will not be able to cope with the fall in revenue and would shut down.
    - As discussed on the previous page, **if miners fall out of operation, those surviving capture a now-outsized portion of the now-reduced block rewards.**

- Instead of "all else being equal," **what has typically happened around block rewards halving is a dramatic run-up in bitcoin price**.
  - In the twelve months following the prior three halvings (2012, 2016, and 2020) BTC spot price increased 84x, 3.4x, and 6.6x, respectively.
  - At 24-months after each prior halving, BTC spot price remained at 31x, 9x, and 3.6x its pre-halving levels.
  - In the past, when daily BTC production was a significant portion of trading volume, the miners' decision to sell or not sell their daily production could materially influence available supply and help buoy BTC spot prices when they were especially low.
    - Today, however, only 450 BTC are created each day (~$29mm worth), while daily trading volume has exploded into the tens of billions of dollars. Therefore, whether bitcoin miners sell 100% or 0% of their new production, they cannot meaningfully influence overall BTC spot prices. Bitcoin miners are now price takers and the limited new supply of bitcoin means that spot price movements going forward will primarily be driven by adoption rates and overall macroeconomic environment, and NOT halving dynamics.

- **The highest margins and the safest operating position will be held by those miners with the lowest cost of energy as they can outlast competitors and capture an outsized share of the rewards.**

DPO believes the impact of BTC price movement on proof-of-work data center investment returns is dramatically misunderstood by the market. As long as the data center has access to truly undervalued energy, it will remain profitable over time regardless of BTC spot price.

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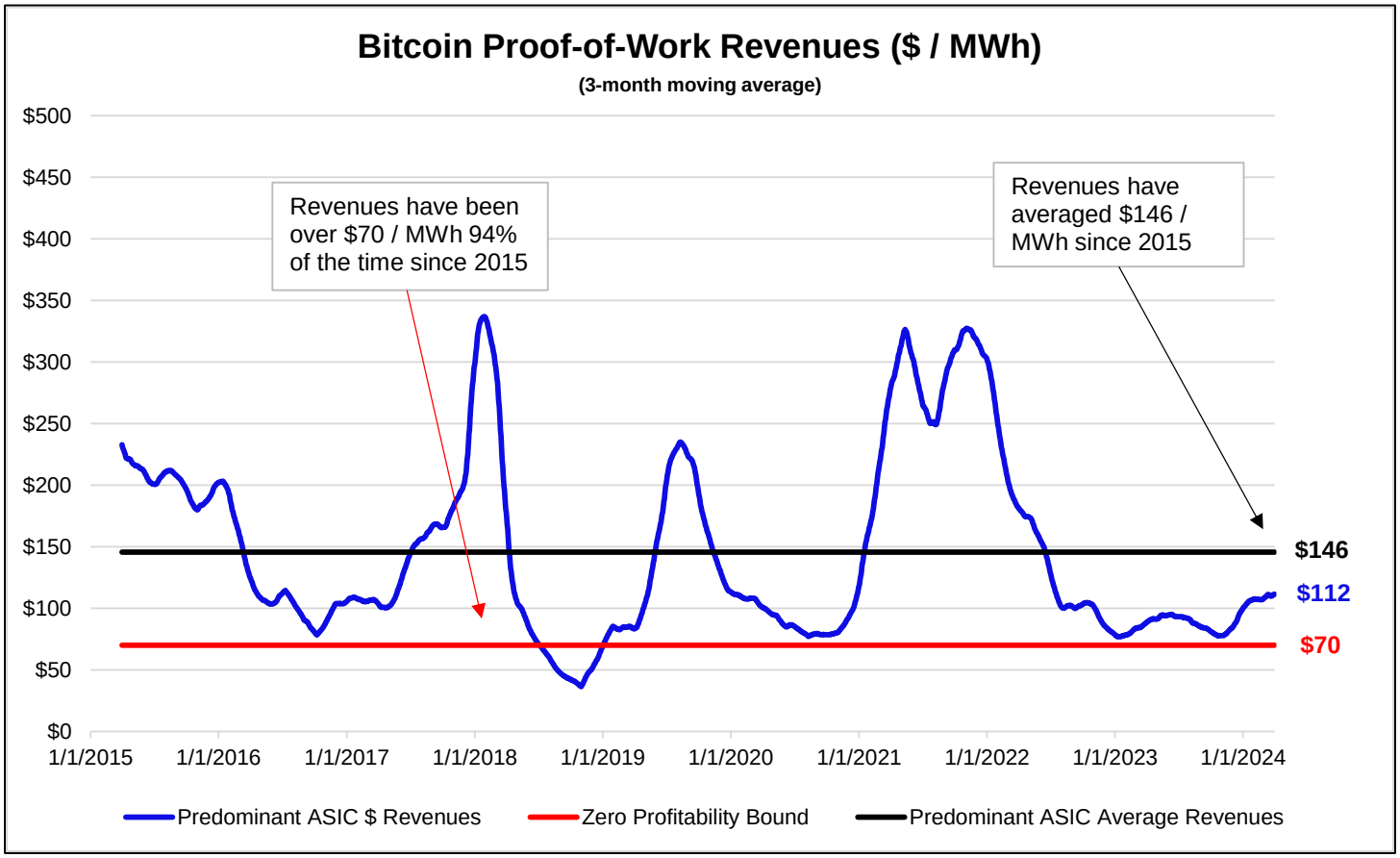
This chart shows bitcoin mining in the context of $/MWh. Depending on BTC spot price and network difficulty, the overall gross revenue capture can vary significantly. Historically this revenue bottoms near $70/MWh because that is the approximate limit where the average bitcoin miner can no longer operate profitably (assuming $50/MWh power cost and $20/MWh of other operating expenses). **Since 2015, bitcoin mining revenues have exceeded $70/MWh for 94% of the time, and averaged $146/MWh during that same period.**



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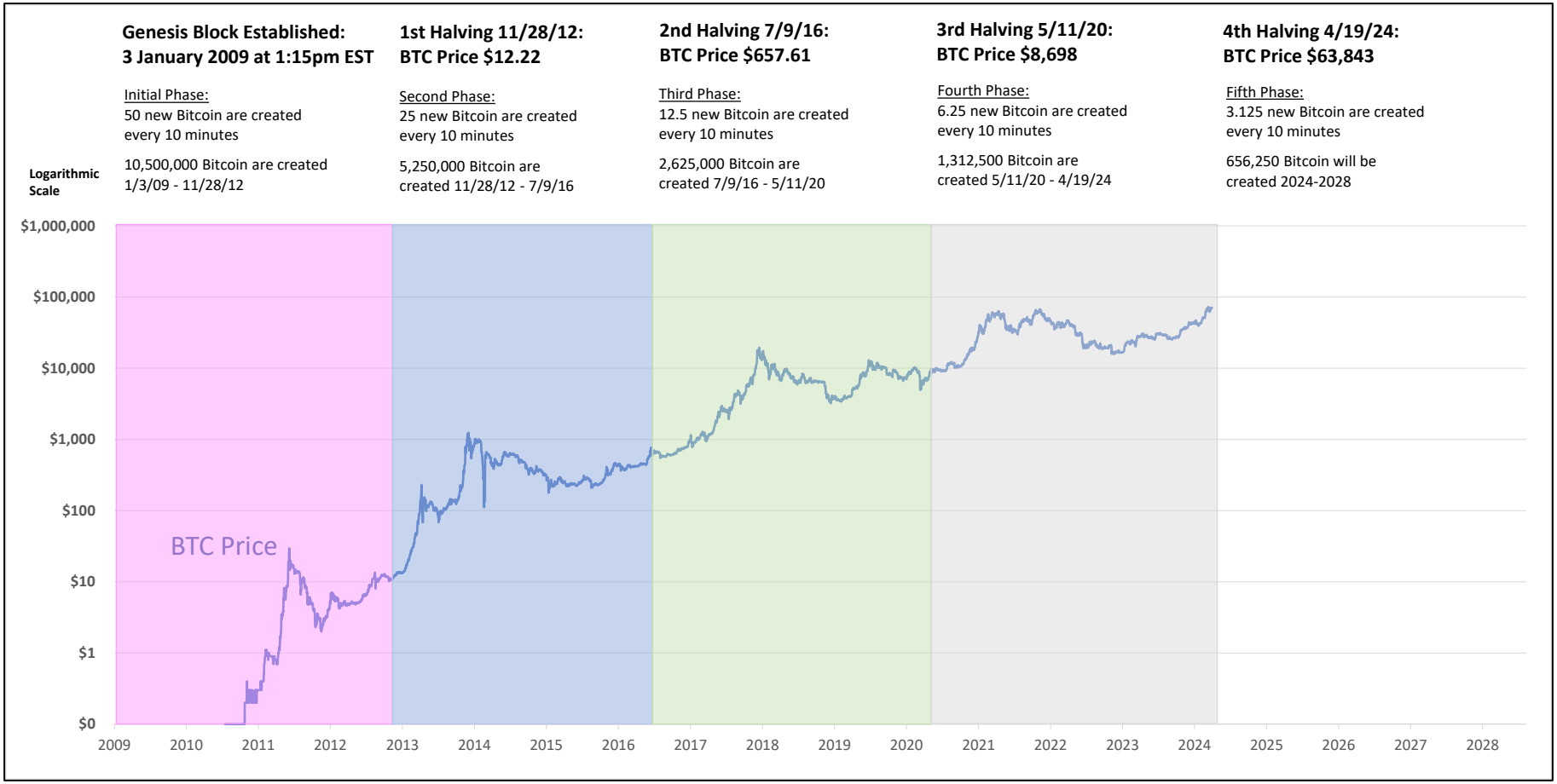
This chart shows the separate phases of Bitcoin block rewards and the associated halving dynamics. Each colored zone is a different "era" with a distinct amount of block rewards (50, 25, 12.5, 6.25, or 3.125) per each 10-minute block.



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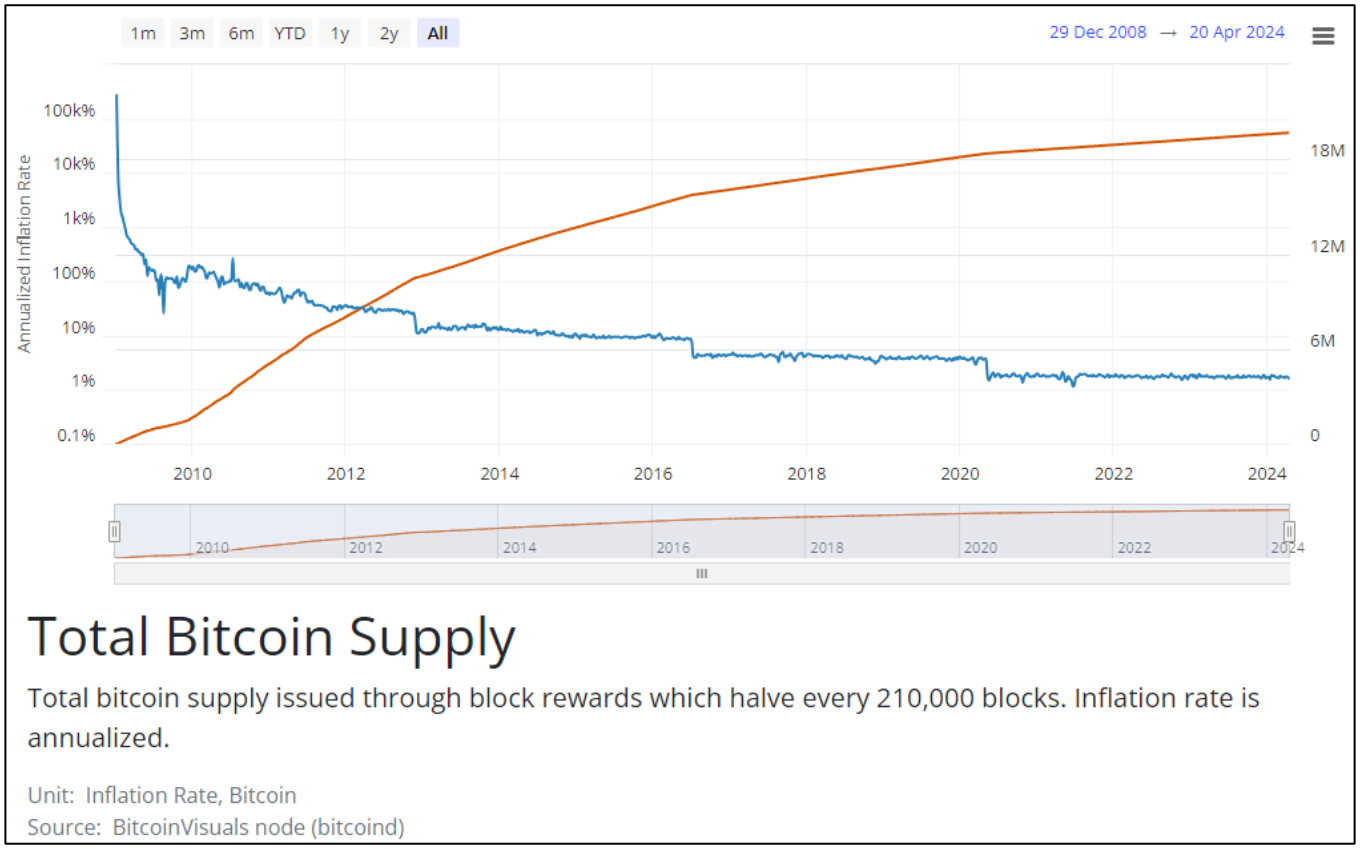
Despite only 13 years of history and mining operations, a significant majority of all potential bitcoin have been mined…approximately 19.7mm of the 21mm maximum. We are now entering the steady-state and low-inflation (in units) stage of Bitcoin's life and expect the limited new supply of coins to put upward pressure on the price as cryptocurrencies gain broader acceptance and wider adoption.

Globally, and in US$ terms, there are more than 21 million millionaires (about 55 million, in fact). Since there are only ever going to be 21 million bitcoin, if every millionaire on Earth tries to acquire just one bitcoin each, there will not be enough to satisfy the demand. There are simply not enough coins to go around. This is mathematically guaranteed digital scarcity.



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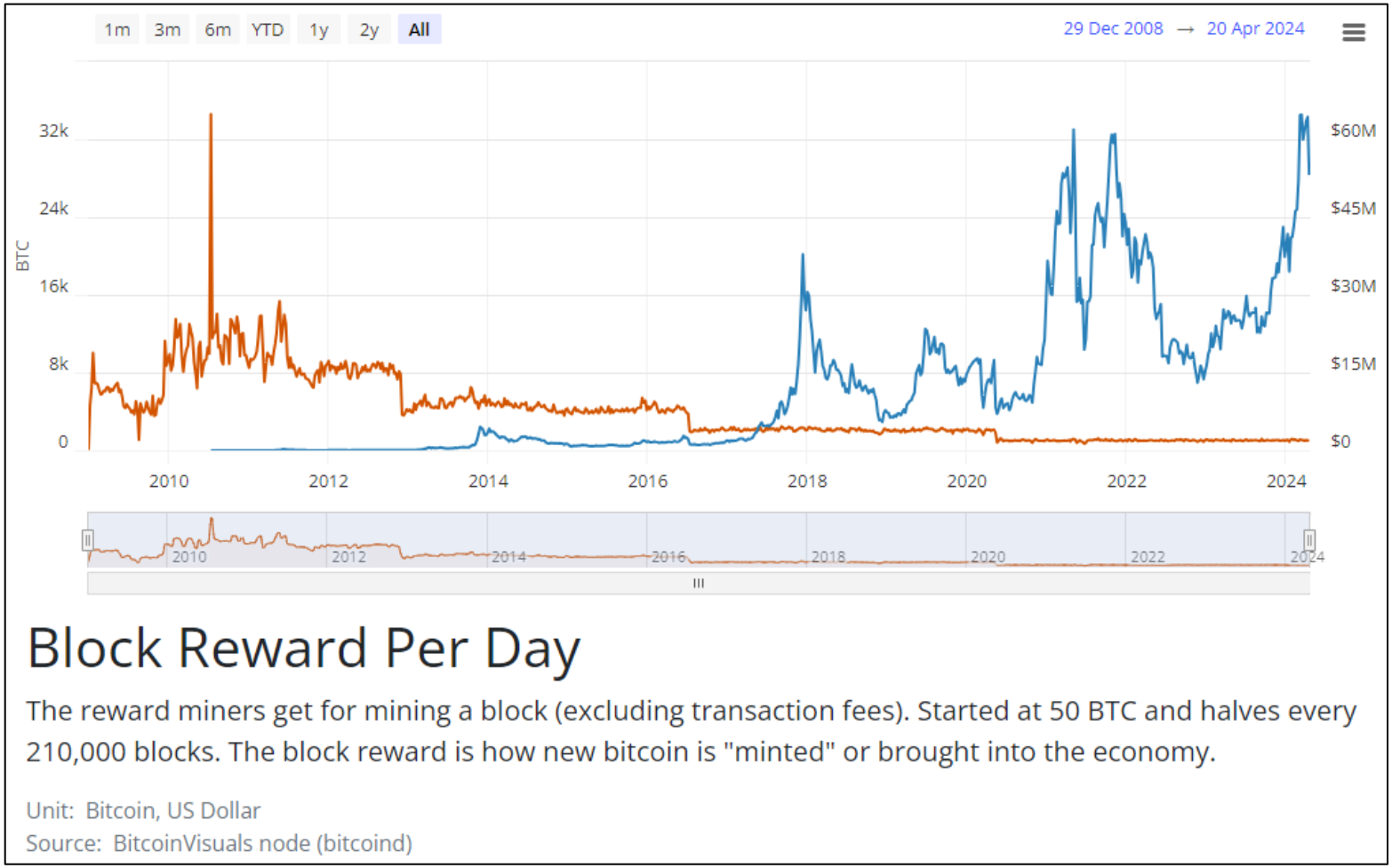
The orange line below shows the number of bitcoin awarded per day as block rewards to miners. (Note the halvings in 2012, 2016, 2020 and 2024). The blue line shows the US$ value of those rewards at the time they were given…essentially daily production multiplied by bitcoin's spot price. Today, there are ~450 new bitcoin being mined per day, worth around $29.3mm assuming today's ~$65,000 spot price, or **approximately $10.7bn per year in total**.



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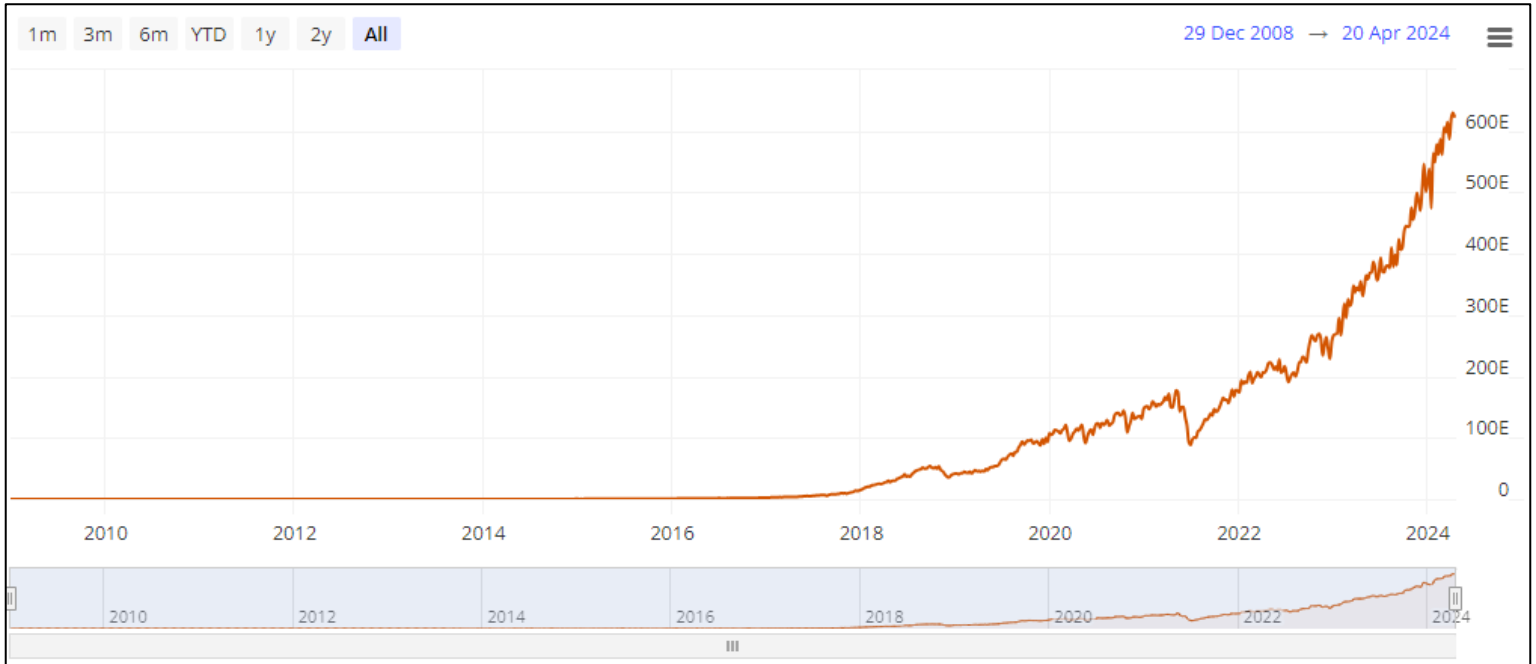

Mining Hash Rate

This chart shows an estimate of how many hashes per second bitcoin miners are performing on the network. Estimate = difficulty * 2^{32} / time. The bitcoin network has a global block difficulty that adjusts every 2016 blocks (~2 weeks) based on a target time of 10 minutes per block. As difficulty increases, more hashpower must be added to have the same statistical chance of finding a block. The time between bitcoin blocks can vary dramatically if there is a large increase or decrease in hashpower within this 2 week period.

Unit: Hashes per second
Source: BitcoinVisuals node (bitcoind)

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Bitcoin Difficulty

The bitcoin network has a global block difficulty that adjusts every 2016 blocks (~2 weeks) based on a target time of 10 minutes per block. Valid blocks must have a hash below this target, therefore difficulty is a measure of how difficult it is to find this hash. As difficulty increases, more hashpower must be added to have the same statistical chance of finding a block. The time between bitcoin blocks can vary dramatically if there is a large increase or decrease in hashpower within this 2 week period.

Unit: N/A
Source: BitcoinVisuals node

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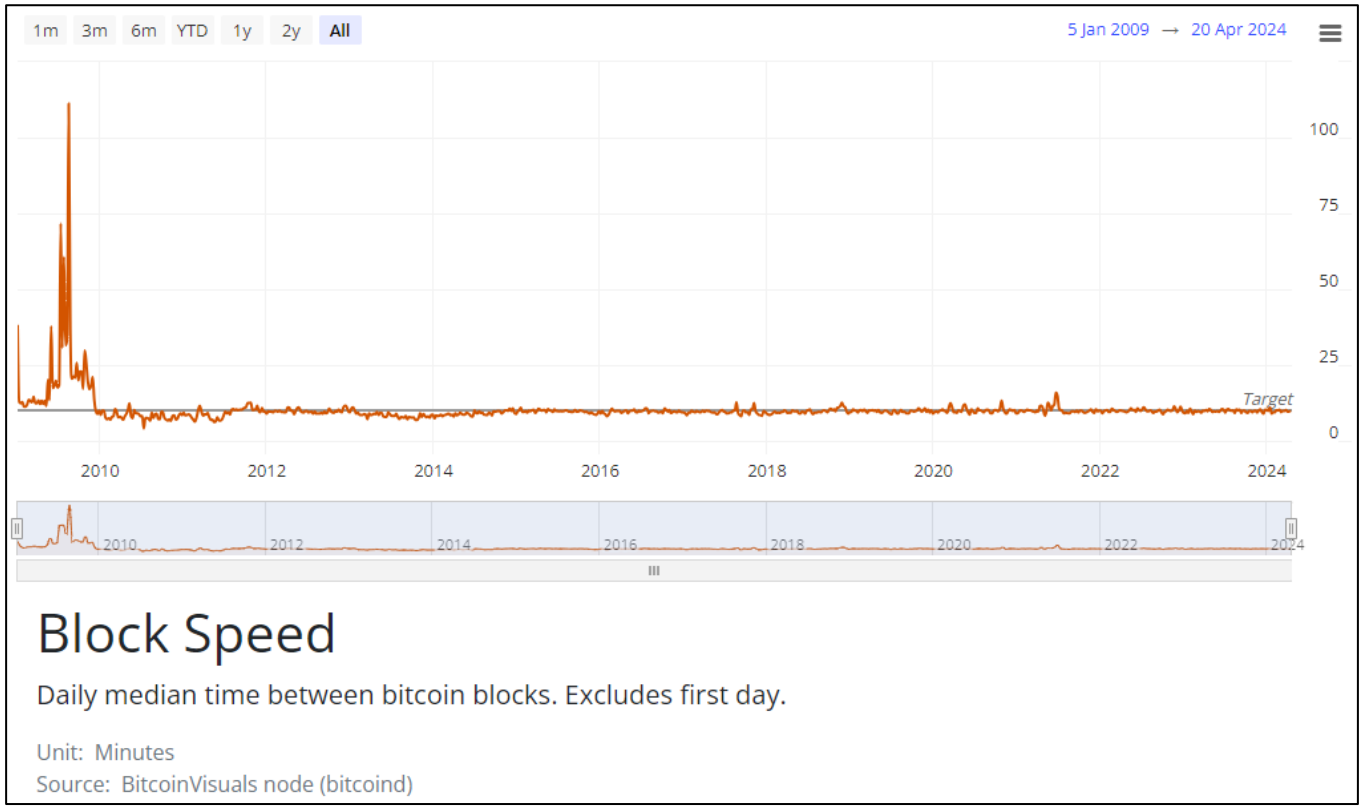
This shows the efficiency of the Bitcoin algorithm in adjusting the difficulty of mining to match a target 10-minute interval for the block rewards. This period stays 10 minutes no matter how much computing power is thrown at the blockchain and is why **the coins will be mined no slower and no faster than prescribed by the algorithm**. This is what creates scarcity and prevents miners from flooding the market with new bitcoin earlier than prescribed. Compare this to the charts on the previous two pages showing the dramatic increase in hash power coupled with the simultaneous rise in difficulty, resulting in a steady 10-minute interval despite the extreme increase in computing power.

THIS MECHANISM is what turns bitcoin mining into a race to the cheapest and most secure power, rather than simply a race to acquire more mining equipment.



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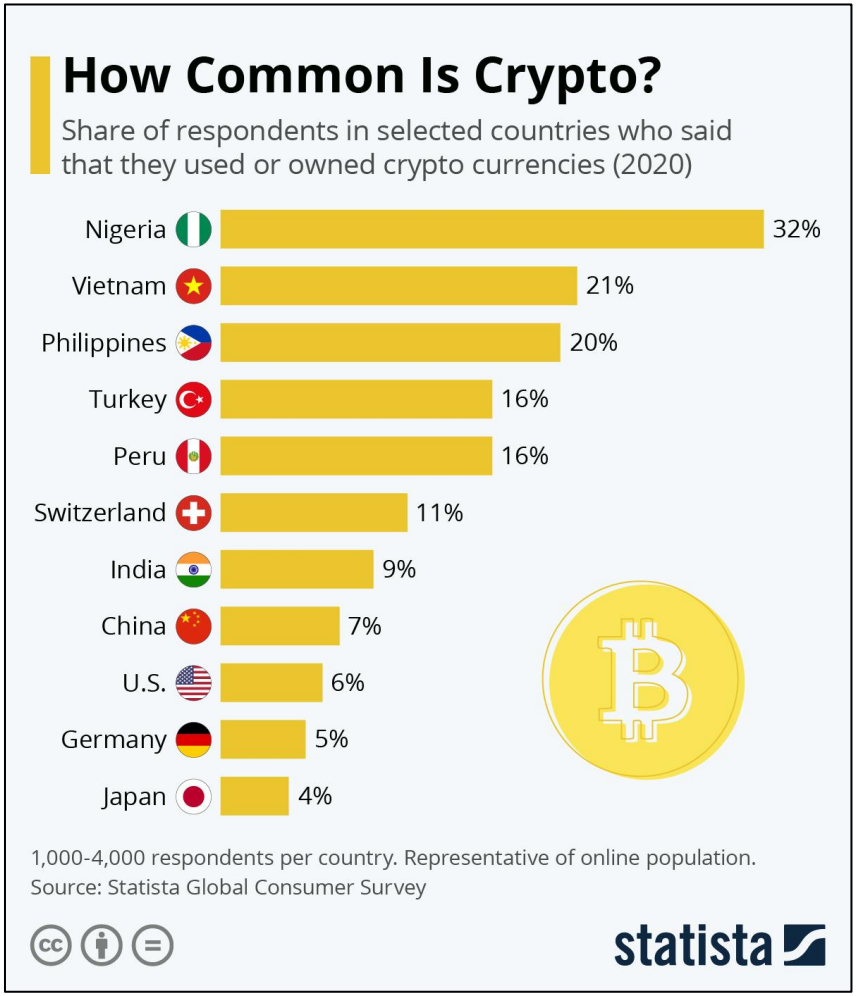
Cryptocurrencies are NOT primarily a U.S. phenomenon and there is tremendous room for growth in some of the world's wealthiest countries.



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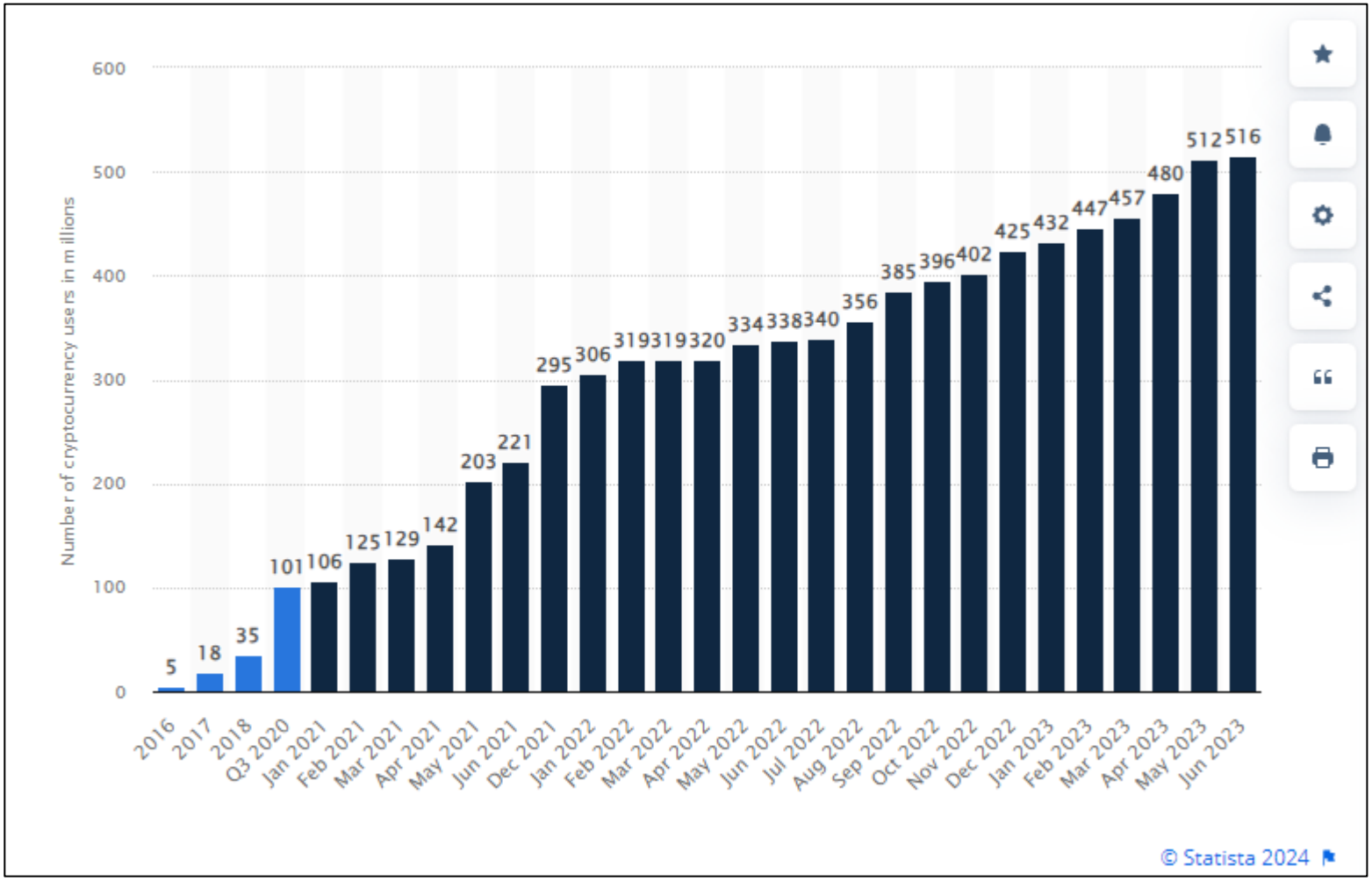
Global growth of cryptocurrency users remains robust despite 2022 market turmoil.



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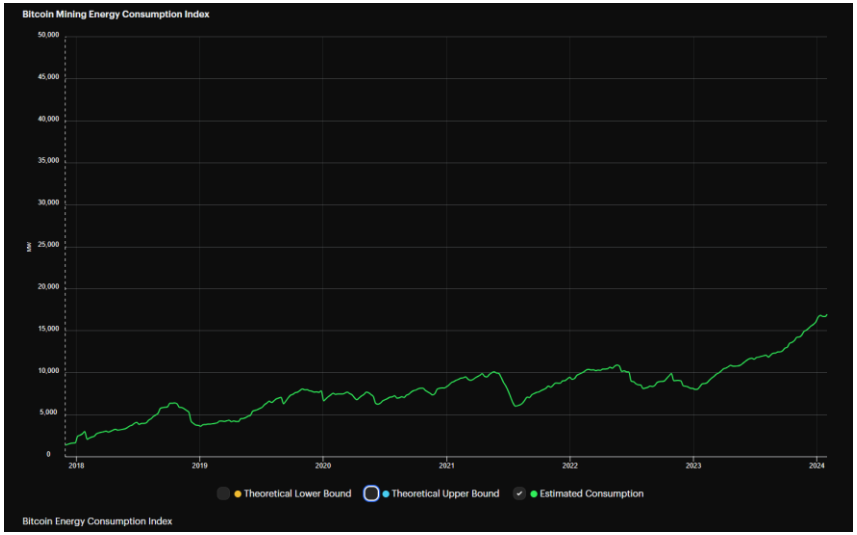
- ***How much energy is Bitcoin/blockchain/cryptocurrency technology using, how dirty is it, and how much does it cost?*** Those things can be estimated, but not calculated.
  - The "hash rate" is a known and transparent quantity, but we cannot accurately know how many mining computers were running to produce it, how clean or dirty the source of power, or how much that end-use electricity is actually costing the miner. Everything we see and read in the press on those topics, at least when taken in aggregate, are estimates. **Today, Bitcoin's total estimated energy usage is around 16.9 GW, or 148 TWh per year; some estimates are even higher.**
- Luxor's Bitcoin Mining Energy Consumption Index (chart below) is known within the industry as a reliable 3rd-party estimate and takes into account various other academic studies in reaching its estimates, such as Hileman & Rauch's 2017 "Global Cryptocurrency Study" and the 2019 Cambridge Bitcoin Electricity Consumption Index (CBECI).
  - What seems clear from all research and observable inputs, is that the use of energy to mine bitcoin has skyrocketed with its price in 2017-2018 and again in 2020-2021, which again makes sense as a wider margin will attract more and more capital and more and more computers to the industry, as further evidenced by the increasing hash rate.
  - **At higher bitcoin prices, more energy will be used.** If the price of bitcoin reaches some predictions of $100,000 or $500,000 or $1,000,000 per coin, the amount of energy required…**green energy by regulatory mandate**…will be immense.

"But mining bitcoins remains profitable, so the amount of hardware it uses and the quantity of electricity it inhales will continue to surge dramatically for years. Another price spike could push energy use even higher. "We fundamentally don't know how high the price of bitcoin will go," Bendiksen said. "If the bitcoin price goes up by 10x, you would expect the energy consumption of the network to also go up by 10x."

-- U. Ifran via Vox.com 6/18/19: "Bitcoin is an energy hog. Where is all that electricity coming from?"



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Parting thoughts on bitcoin mining vs traditional mining:

Imagine if all of the gold miners on Earth could only extract (and would always extract) a set amount of gold per day, regardless of how much (or how little) heavy equipment they used to extract it or how many mines they collectively operated.

Imagine if there were 10 gold miners on Earth and each extracts 1,000 oz of gold per year. Three go out of business due to mismanagement or perhaps political disruption in their country halts operations indefinitely, leaving seven. Those remaining seven, however, now receive the share of those shuttered gold miners as though they were still operating. Those 3,000 oz of gold per year are still being "extracted" and distributed to the remaining 7 miners, but those remaining miners don't have to operate additional machinery or change their operations in any way. So now each remaining miner is suddenly extracting 1,428 oz per year, but doing no additional work.

Imagine if gold miners knew exactly how much gold they would extract week-to-week and day-to-day with the certainty of a mathematical calculation and knew exactly when the world's supply would run out.

Imagine if gold miners didn't need to process or physically transport their product and could instead transmit it through the air at virtually the speed of light immediately upon extraction.

Imagine if the custody chain of the product being mined is 100% transparent to everyone with a computer from the moment it is extracted.

Imagine if cryptocurrency mining becomes (or perhaps already is) the global marginal buyer of energy, essentially transferring the economics of Bitcoin to the power and energy industry, thus driving an explosion of investment in search of cheap green energy which would otherwise not have occurred without this massive marginal buyer. In other words, imagine if crypto is the "Trojan Horse" that forces green energy upon the world at a rate far faster than would have otherwise been thought possible with traditional economic structures.

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Additional 3rd-Party Resources:

Fidelity: Bitcoin Investment Thesis (July 2020)
https://www.fidelitydigitalassets.com/sites/default/files/documents/bitinvthessisstoreofvalue.pdf

Fidelity: Bitcoin First (January 2022)
https://www.fidelitydigitalassets.com/sites/default/files/documents/bitcoin-first.pdf

Fidelity: Valuing Bitcoin (June 2022)
https://www.fidelitydigitalassets.com/sites/default/files/documents/valuing-bitcoin-report.pdf

KPMG: Bitcoin's Role in the ESG Imperative (August 2023)
https://advisory.kpmg.us/content/dam/advisory/en/pdfs/2023/bitcoins-role-esg-imperative.pdf

Square (Block) / ARK Invest White Paper (April 2021)
https://assets.ctfassets.net/2d5q1td6cyxq/2D2BnksJjavw4a6SUvAPwZ/c42a9e3a520b0cc3b230cda3b43eead5/BCEI_White_Paper_.pdf

MetLife Investment Management (January 2021)
https://investments.metlife.com/content/dam/metlifecom/us/investments/insights/research-topics/macro-strategy/pdf/MIM-GEMS-The-Blockchain-Blockbuster_Yapese-Stones-to-Central-Bank-Digital-Currencies.pdf

"What if? Energy as Money" – Gautschi, Gautschi, and Tucci (2015)
https://econpapers.repec.org/article/gamjjrfmx/v_3a15_3ay_3a2022_3ai_3a4_3ap_3a168-_3ad_3a788609.htm